Verification of Snake River Streamflow Augmentation: a case study of the Payette River

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Prepared by:
Dr. Roy W. Koch, Portland State University

ABSTRACT

The U. S. Bureau of Reclamation (BOR) releases stored water to augment instream flows to benefit outmigrating Snake River salmon in accordance with Biological Opinions issued by the National Marine Fisheries Service in 1995 and 1998. This study evaluated the adequacy of currently available tools in verifying that these releases are not diminished by diversion prior to reaching Hell's Canyon, the upstream terminus of currently occupied habitat. Also, one of these tools, the Idaho Department of Water Resources Accounting Model, was selected for a case study tracking BOR's releases in the Payette River basin during the summer of 1996.

Two models currently exist that could potentially be used for the purposes of flow verification: the Snake River Operations Model (SROM), and the Idaho Department of Water Resources (IDWR) Accounting Model. Each was evaluated for its suitability in performing the required calculations. The IDWR Accounting Model is currently used by IDWR to track water allocation throughout the Snake River basin.

Given the importance of system dynamics in accurately tracking and identifying the sources of streamflow it was determined that a daily time step was necessary. Unfortunately, the SROM was designed to operate on a monthly time step and, due to the inaccessibility of its source code, it was not possible to determine if the model could be modified to operate on a daily time step. We therefore determined that the IDWR Accounting Model is the best currently available tool to verify delivery of water released by BOR for instream flow augmentation. Our analysis found the IDWR Accounting Model to be simple, yet robust and relatively insensitive to errors with regard to estimating the quantities of water released for instream flow.

An evaluation of the amount of stored water released for flow augmentation purposes in the Payette River basin during the summer of 1996 was performed using IDWR's Accounting Model. This assessment showed that the model accurately calculated the accumulation of flow released from storage passing the Letha gage, the point in the Payette River basin where the water released for flow augmentation is calculated. However, a similar calculation performed at the downstream Payette gage indicated that a lesser amount of stored water actually reached the Snake River. Further evaluation revealed that the river gains a considerable amount of flow in this lower river reach and that this accrued streamflow is then subject to diminishment through unmeasured diversions. The calculations inherent in the IDWR Accounting Model automatically assign these withdrawals to storage rather than natural flow, even though sufficient natural flow may be available. We conclude that while IDWR's Accounting Model is the best available tool to track release and delivery of water for salmon flow augmentation, ungaged diversions can lead to errors in the calculated contribution of stored water releases to streamflow. This error diminishes the model's ability to track BOR's salmon flow augmentation releases in the Payette River basin to the Snake River.

1.0 Introduction

On March 2, 1995 the National Marine Fisheries Service (NMFS) issued a Biological Opinion (BiOp) under the Endangered Species Act for the operation of the Federal Columbia River Power System. To avoid jeopardizing the continued existence of the listed salmon species in the basin, a reasonable and prudent alternative was developed that, among other measures, seeks to provide an additional 427,000 acre feet of in-river flow to enhance out-migration conditions for juvenile salmon. This volume of flow is taken from a combination of natural flow rights, uncontracted storage, and water rental in the basin.

1.1 The Problem

This report arose from an interest in verifying that the amount of streamflow required under the BiOp has, in fact, been released and further, that the releases have reached the required point downstream. Although this may seem like a straightforward accounting problem, the complex combination of natural hydrologic processes and extensive water use in the basin make this determination a complex process.

Briefly, the typical approach to such issues is to develop a water balance for the river system, usually on a reach by reach basis, and account for the water flowing into and out of each reach. Demonstrating that flow released from a reservoir reached a particular point is a simple matter of simulating the system without the release and comparing the expected outflow with no release to the actual measured outflow. The difference, accounting for the effects of travel time and the attenuating effects of flow within the reach, is an estimate of the amount of the release that reached the outlet. Problems arise when one or more components of the water balance, for example the natural accretion due to baseflow and tributary inflow, return flow or some of the diversions, are not measured. Under these circumstances, closing the water balance becomes difficult and may contain considerable uncertainty thereby affecting the estimate.

1.2 Study Objectives

The general objective of this study is to evaluate whether the currently available tools and methods available for use in verifying releases for streamflow augmentation are adequate for the task. There are three specific objectives:

- Evaluate the suitability of the Snake River Operations Model (SROM), a proprietary computer program developed for the National Marine Fisheries Service for use in evaluating the distribution of streamflow in the Snake River Basin, for the task of verifying the releases.
- Evaluate the water accounting model used by the Idaho Department of Water Resources (IDWR), a program used to both account for water use and assist in water distribution.
- Make recommendations, as appropriate, regarding the suitability of these models for the purpose of verifying the release of flow as required by the Biological Opinion and for improvements in these approaches or new approaches that may be required to better assist in this task.

1.3 Approach

The Snake River basin is a complex hydrologic system due to its geology, which allows for both the loss and subsequent recharge of a significant volume of water from the river channel, and is further complicated by the extensive control and use of water in the basin. As a result of this complexity it was determined that the evaluation of the suitability of the existing tools for the entire Snake River basin would not be within the scope of the study. Rather, it was agreed that a representative tributary stream would be selected and evaluated as a case study to determine the effectiveness of the current analysis tools. This example would then provide the basis for recommendations on the suitability of those tools and the improvements required if they are to be used by the NMFS in verifying that the required flow has reached the desired location downstream.

The approach taken in this investigation is as follows:

- Evaluate the SROM and IDWR accounting models regarding their suitability for verifying releases,
- Select a tributary to the Snake River to be used as a case study,
- Identify and collect all of the data for the selected tributary basin related to streamflow and water use that is required by the models and is relevant to the verification of releases required by the Biological Opinion,
- Identify uncertainties that may result from the model configuration, data availability or a combination of the two.

Such an evaluation will allow the NMFS to assess the accuracy of the streamflow estimates produced by the various models used to verify that reservoir releases do, in fact, contribute to flow at the required location.

2.0 The Payette River Basin as a Case Study

To evaluate the ability of the IDWR Accounting Model to verify reservoir releases for downstream delivery to augment instream flow, a case study approach was selected. This approach was deemed appropriate given the complexity of the Snake River basin as a whole, the current understanding of the model and data availability and the scope of the project. As a result, a search was undertaken to select a tributary stream within the Snake River basin to serve as the basis for the case study.

2.1 Selection of the study area

The following criteria were used to select a specific river basin in which to evaluate the Accounting Model's suitability to verify the delivery of stored water for streamflow augmentation.

- The basin must be located within the Snake River basin as the overall objective is to verify that flow released from the reservoirs in the basin had, in fact, reached the downstream point.
- The study area should be representative of the Snake River basin in terms of water use and water control structures; that is there should be significant diversion of flow and a significant amount of water storage.
- Data describing the hydrology and water use in the basin should be generally available and complete.
- There should be some prescribed reservoir releases for instream flow augmentation in the basin so the evaluation will also provide a quantitative assessment for at least a potion of the basin.
- The IDWR Accounting Model should be running in the basin because it is the only existing model that has a potential for use in verifying instream flow releases.

In applying these criteria, consideration was given to three areas within the basin: the Upper Snake River (Snake River above Milner Dam), the Boise River, and the Payette River basins. Releases for instream flow augmentation are required from each of these basins; each is of a reasonable size and generally meets the criteria. The Upper Snake River was eliminated from consideration for this evaluation due to some significant complexities in the hydrology caused by the geology of the area. Of the remaining two candidate basins, the Payette River was selected due to the much larger volume of flow required for instream flow augmentation from that basin.

2.2 The Payette River basin

The Payette River basin, located in south eastern Idaho, has a drainage area of approximately 3,270 square miles at its confluence with the Snake River, near river mile 365 on the Snake. The watershed is diverse in topography and land use ranging from intensive irrigated agriculture along the lower reaches above Payette, elevation approximately 2,100 feet, to relatively undeveloped, mountainous areas in the headwaters of the North and South Forks where elevations exceed 8,500 feet.

2.2.1 Hydrology and water management

The Payette River has its source in the Salmon River Mountains of central Idaho. The main stem of the Payette is formed by the confluence of the North and South Forks near Banks, Idaho, flowing south to Horseshoe Bend then generally west to its confluence with the Snake River at Payette, Idaho. A schematic of the river system is presented in Figures 1a and 1b that includes the major streams, locations of major tributaries and diversions, and selected towns and settlements for the purposes of orientation. The North Fork (Figure 2.1a) flows generally south, has a drainage area of approximately 950 square miles, and is controlled by several storage reservoirs, the most significant of which is Cascade Reservoir located near Cascade, Idaho. Payette Lake and Lake Fork reservoirs also provide some control. The South Fork (Figure 2.1b) flows generally west toward the confluence where the drainage area is approximately 1,200 square miles, being joined along the way by its major tributaries, the Deadwood River and the Middle Fork of the Payette River. Deadwood Reservoir is located on the Deadwood River about 24 miles above the confluence of the Deadwood River with the South Fork. The main stem of the Payette River flows generally south from the confluence of the North and South Forks to Horseshoe Bend and then west to its confluence with the Snake River at Payette, Idaho. A major control structure, Black Canyon Dam is located on the main stem of the Payette River upstream from Emmett, ID at river mile 38.7. Although Black Canyon Dam raises the water elevation over 110 feet, it is a diversion structure with no significant storage.

Streamflow in the Payette River basin originates largely in the upper portions of the basin as a result of the accumulation and melting of a seasonal snowpack. Under natural conditions, peak flows occur in May or June, depending on location and weather conditions. An illustration of the annual cycle of streamflow for selected locations in the Payette River basin is given in Figure 2.2. In this figure, the hydrographs for the South Fork near Lowman and North Fork at McCall represent the natural variation of streamflow throughout the year, with the exception that there is some regulation due to Payette Lake on the North Fork. Both show the peak flow in June and low flows through the late summer, fall and winter months. The hydrograph for the North Fork below Cascade Reservoir shows the impact of the reservoir operation on the natural hydrograph; a reduction of the peak and increases during low flows, particularly in the summer and early fall. Historical records indicate that the majority of flow, nearly 60 percent, originates in the South Fork while the remainder comes from the North Fork. However, the records may not accurately represent the distribution of natural flow because they include the effects of diversions and consumptive uses as well as reservoir evaporation.

Figure 2.1a. Schematic of the North Fork and main stem of the Payette River below the confluence of the North and South Forks showing the location of major tributaries, diversions and selected towns and settlements.

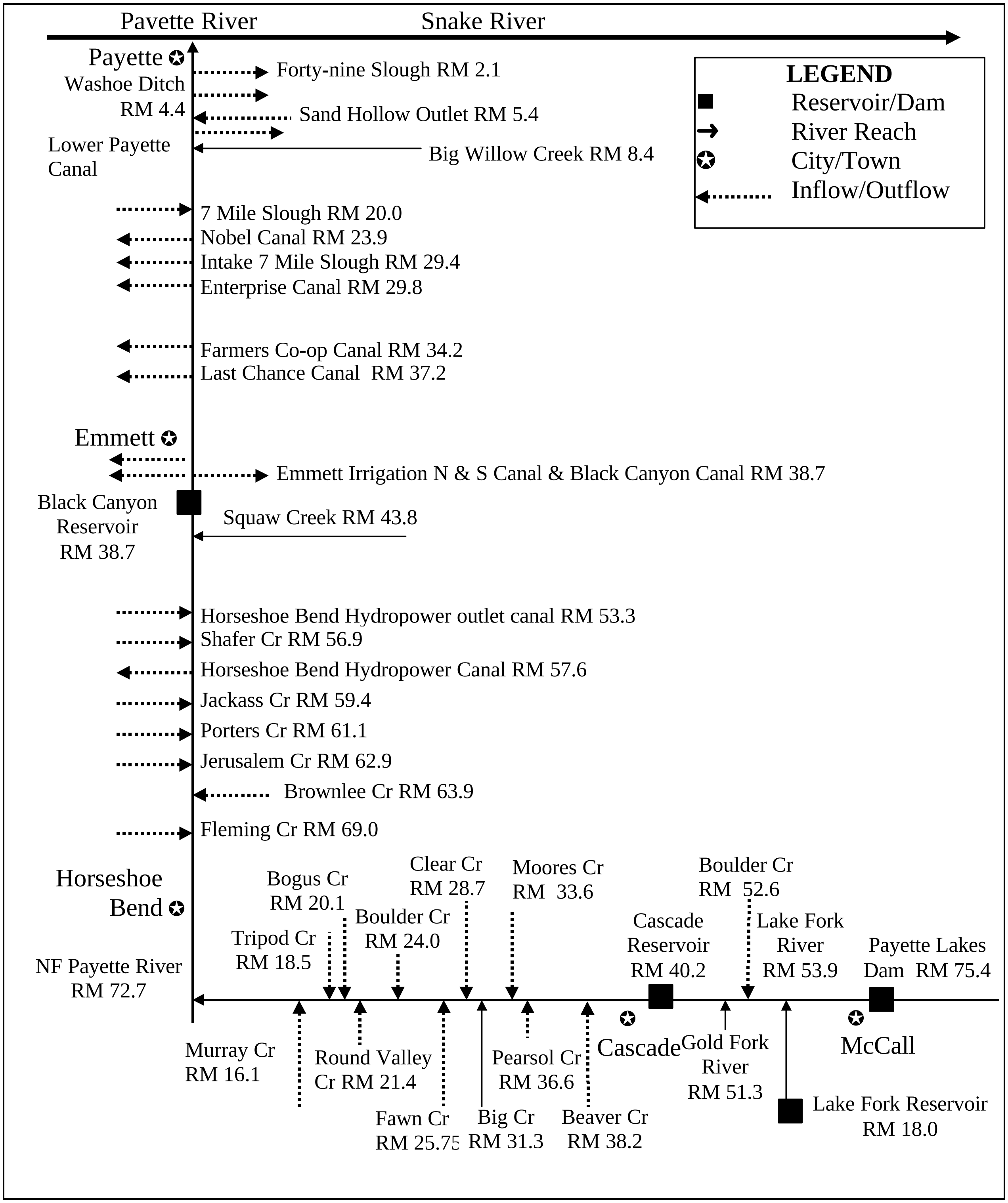


Figure 2.1b. A schematic of the South Fork of the Payette River showing the location of major tributaries, diversions and selected towns and settlements.

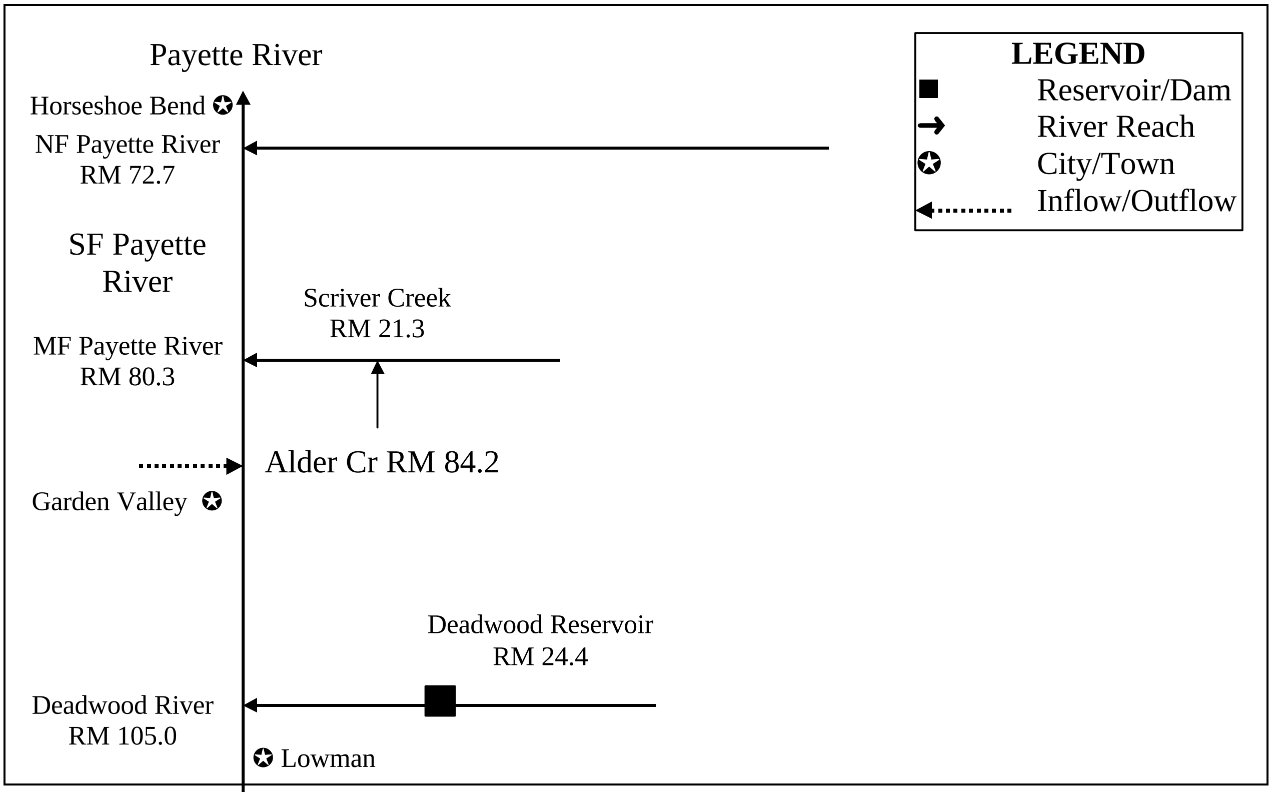
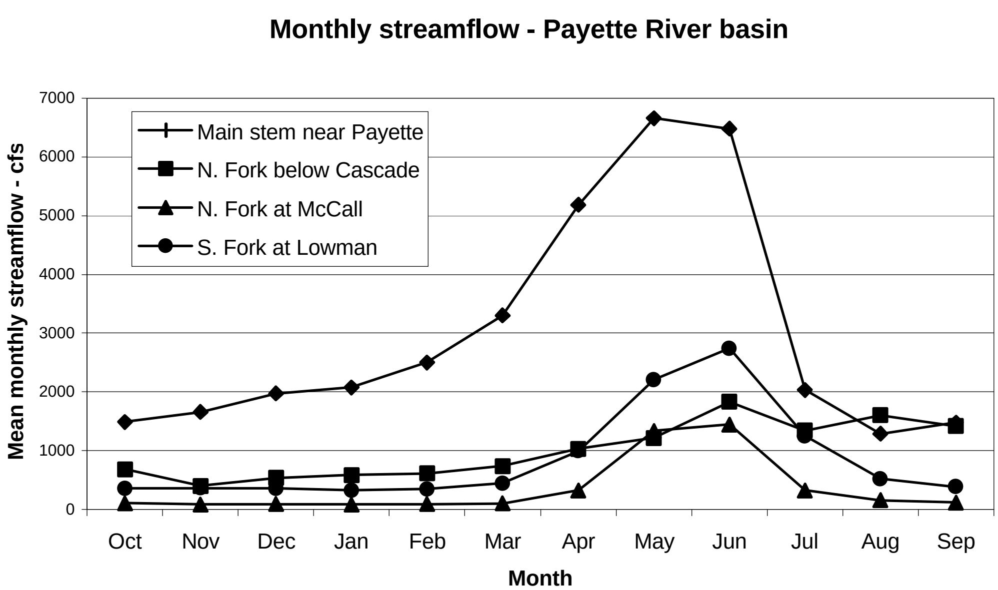


Figure 2.2. Hydrographs for selected locations in the Payette River basin demonstrating the annual cycle of streamflow and the effects of reservoir storage.



2.2.2 Hydrologic data

Streamflow and reservoir storage are monitored at a several locations in the Payette River basin and form the basis for the IDWR Accounting Model. The locations of existing and inactive streamflow gaging sites in the basin are shown in Figure 2.3. A description of each site, including the drainage area above the gage, period of record and the types of data observed is presented in Table 2.1. Although the period of record for the active locations indicates an ending date of 1996, this is due to the current availability of data. Each of these sites is currently operating. Additional information related to the water use and water control structures above selected sites, as reported by the U.S. Geological Survey, is presented in Table 2.2. The U.S. Geological Survey, Water Resources Division, collects most of the streamflow data in the basin.

Figure 2.3. Schematic of the Payette River basin showing the location of both active and inactive (historic) gaging sites. Inactive sites are shown in Italics.

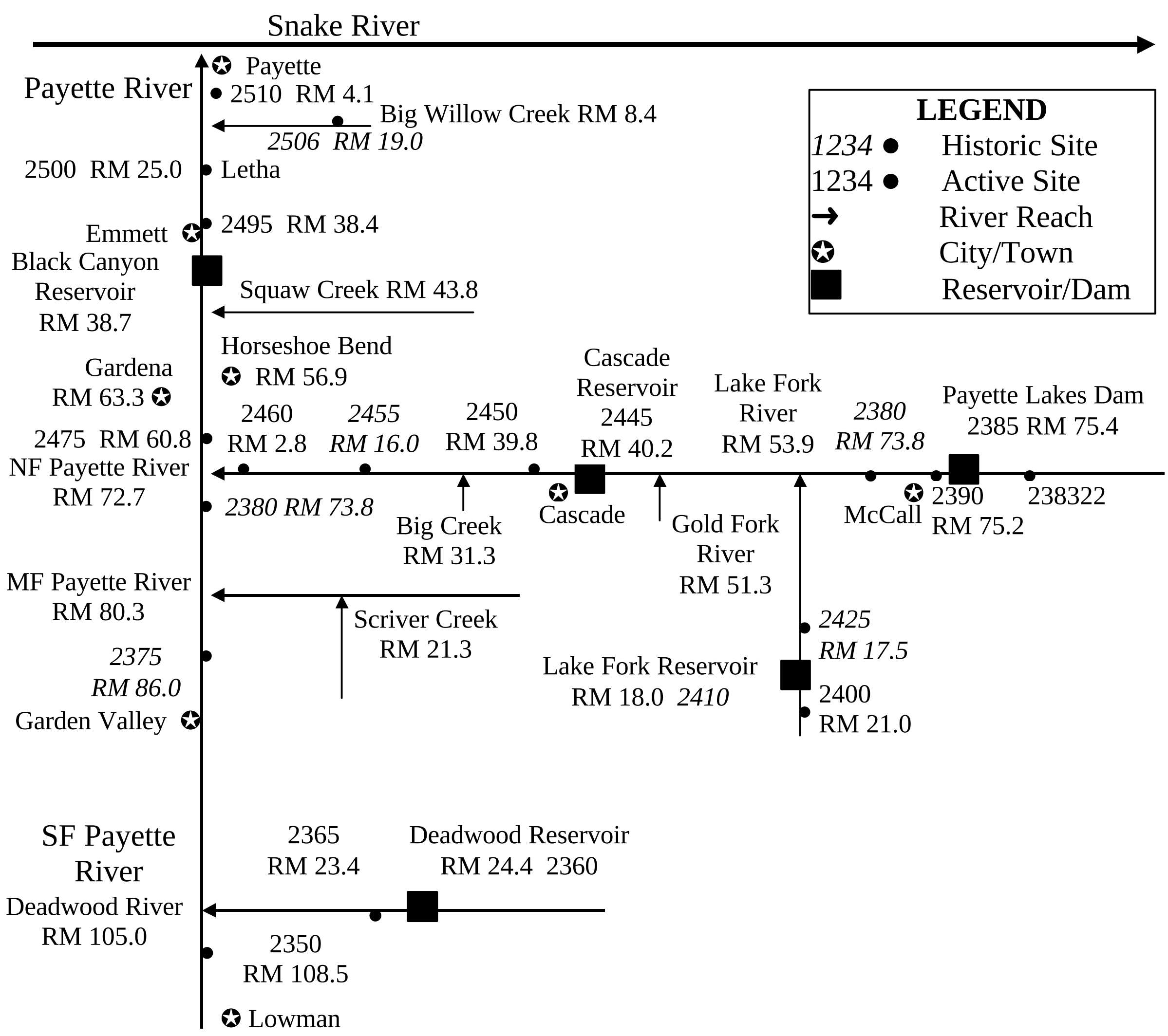


Table 2.1. Description of the active and inactive gaging sites in the Payette river basin. Relative locations are shown in Figure 2.2.

Gage #	River Mile	Site Name	Drainage Area, mi^2	Period of Record	Collected Data *	Notes
2510	4.1	Payette River near Payette	3240	1935-96	DQ	1
2500	25.0	Payette River near Letha	2760	1994-96[a]	DQ	
2495	38.4	Payette River near Emmett	2680	1925-96	DQ	
2475	60.8	Payette River near Horseshoe Bend	2230	1919-96	DQ	
2460	2.8	NF Payette River near Banks	933	1947-96	DQ	
2450	40.0	NF Payette River at Cascade	620	1941-96	DQ	
2445	40.2	Cascade Reservoir at Cascade	620	1949-96	ELEV	2
2400	21.0	Lake Fork Payette River above Jumbo Creek near McCall	48.9	1945-96	DQ	
2390	75.2	NF Payette River at McCall	144	1919-96	DQ, WQ	
2385	75.4	Payette Lake at McCall	144	1921-96	DQ	
238322		NF Payette River below Fisher Creek near McCall		1994-9/95	DQ,WQ	3
2365	23.4	Deadwood River below Deadwood Reservoir near Lowman	112	1926-96	DQ	
2360	18.0	Deadwood Reservoir near Lowman	112	1935-96	ELEV	4
2350	106	SF Payette River at Lowman	456	1941-96	DQ, WQ, SS	
2506	*19.0*	*Big Willow Creek near Emmett*	*47.5*	*1962-83*	*DQ*	
2455	*16.0*	*NF Payette River near Smiths Ferry*	*893*	*1941-47*	*DQ*	
2425	*17.5*	*Lake Fork Payette River below L.I.D Canal near McCall*	*64*	*1941-74*	*DQ*	
2410	*18.0*	*Lake Fork Reservoir near McCall*	*64*	*1926-73*	*DQ*	
2380	*73.8*	*Payette River near Banks*	*1200*	*1921-74*	*DQ,,TEMP*	
2375	*86.0*	*South Fork Payette River near Garden Valley*	*779*	*1921-60*	*DQ*	

Notes

a Period of record is fragmented, 1978-1983, 1983-1986 (irrigation season only), and 1994-current.

1 Daily discharge for 1/95-7/97 are unreliable.

2 Reservoir capacity table provided by the Bureau of Reclamation (BOR).

3 Possibly a new site and site information not available, located 3 miles above Payette lake.

4 Elevation readings taken at 24:00

Table 2.2. Description of the water use and other characteristics of gaging sites in the Payette River basin as described in USGS Water Resources Data, Idaho, Water Year 1995.

Gage #	Remarks
2510	Flows regulated by Black Canyon Reservoir, 34.6 miles upstream. Diversions above station for irrigation of about 196,000 acres are in adjacent basins, determined 1996.
2500	Flow regulated by Black Canyon Reservoir 13.5 miles upstream. Diversions above station for irrigation of about 190,000 acres, of which 50,000 acres are located below station and 53,000 acres are in adjacent basins., determined 1996.
2495	Flow regulated by Black Canyon Reservoir 0.3 mile upstream. Diversions above station for irrigation of about 160,000 acres, of which 43,700acres are located below station and 53,000 acres are in adjacent basins, determined 1996.
2475	Flow regulated by Cascade and Deadwood Reservoirs, 51.9 mile upstream. Diversions above station for irrigation of about 55,100 acres, determined 1996.
2460	Flow regulated by Cascade Reservoir 37.6 miles upstream. Diversions above station for irrigation of about 50,800 acres, determined 1996.
2450	Flow regulated by Cascade Reservoir 0.2 mile upstream. Diversions above station for irrigation of about 39,000 acres, determined 1996.
2445	Water is used for irrigation of lands in the Payette Division of the Boise Project and for power at Black Canyon powerplant near Emmett. Capacity is 703,200 acre-feet, retaining 50,000 acre-feet as dead storage.
2400	No diversions above station. Flow partially regulated by Browns Pond, capacity 1,230 acre-feet.
2390	Flow regulated by outlet of Payette Lakes, 0.2 mile upstream. Diversion for fish hatchery bypasses station and is returned below gage. Records of daily discharge of this diversion for 1942 to 1953.
2385	Tainter gates regulate flow from the Payette Lake. Lake area is approximately 5,000 acres. No capacity table has been developed. Water is used for irrigation in vicinity of Emmett. No diversions above station.
238322	Partial regulation for irrigation supply from Upper Payette Lake, usable storage capacity 3,000 acre-feet. Granite and Box Lake have usable storage capacities of 2,900 and 1,295 acre-feet, respectively.
2365	Flow regulated by Deadwood Reservoir 1 mile upstream.
2360	Reported capacity is 160,400 acre-feet. Minimum operating level is 5,230 feet for fish protection. Capacity at 5,230 feet is 1,500 acre-feet. Water is used to augment flow of Payette River at Black Canyon powerplant, and since 1956, as supplemental irrigation supply for Emmett Irrigation District and other users. Small diversion from a tributary of Johnson Creek of Salmon River basin to Deadwood River basin for supplemental storage in Deadwood Reservoir was removed in 1988.
2350	No regulation. Return flow from several small irrigation diversions enters river above station.

2.2.3 IDWR Accounting model representation

Due to the Accounting Model's dependence on observed streamflow, the representation of the Payette River basin is based largely on the location of the stream gaging sites. However, the gaging sites are appropriately located at or near confluence's or major water control structures so the identification of reaches between these sites provides a good representation of the basin. The reaches used in the model are listed in Table 2.3 along with the stream gaging sites at the lower end.

Table 2.3. Reaches used to represent the Payette River basin in the IDWR Accounting Model.

IDWR reach number	Reach name	USGS Station Number[1]	Comments
1	South Fork at Lowman	2350	
2	Deadwood below Deadwood	2365	
3	Payette near Banks	No gage	Flow is estimated as the difference between gage 2475 and 2460
11	Upper North Fork	238322	
4	North Fork at McCall	2390	
5	At McCall to Cascade	2450	
17	L. Payette Lake to Cascade	2400	
6	North Fork – Cascade to Banks	2460	
7	Banks to Horseshoe Bend	2475	
8	Horseshoe Bend to Emmett	2495	
9	Emmett to Mid Slough		
13	Combined waste		
12	Below 7 Mile Slough	2500	
10	Letha to Payette	2510	

[1] Refer to Figure 2.3 for location and Table 2.1 for name and other information on stream gaging stations.

2.2.4 Water use and water rights

Water use in Idaho is based on the doctrine of prior appropriation, the dominant principle governing water allocation in the western United States. This doctrine prioritizes the right to use water by the date of first use. Although the state of Idaho grants water rights, water use is managed by the local watermaster, an elected official. This management is based on the priority associated with the individual water use and it is the responsibility of the watermaster to assure that those with the senior rights have water available first during times of shortage. The issue of water shortage has been, to a great degree, alleviated by the construction of storage facilities that redistribute snowmelt runoff, which naturally occurs in the late spring and early summer, into the dryer summer and early fall months. However, there is typically a fee assessed for the use of stored water for the purposes of paying debt service for the construction of the dam as well as operation and maintenance of the facility. The water master is also responsible for regulating and accounting for use of stored water.

A summary of the water rights in the basin is given in Table 2.4 based on the IDWR reach designations. A complete listing of each water right used by the IDWR Accounting Model is included as Appendix A.

Table 2.4. Summary of water rights for the Payette River basin, Idaho.

IDWR reach designation No.	Name	Total Flow - cfs	Total Storage - AF
1	S. Fork at Lowman		
2	Deadwood below Deadwood		82,178
3	Payette near Banks	12.34	
11	Upper N. Fork		3,277
4	N. Fork at McCall	13.19	36,721
5	At McCall to Cascade	210.34	394,618
17	L. Payette Lake to Cascade		
6	N. Fork - Cascade to Banks	55.40	
7	Banks to Horseshoe Bend	13.10	
8	Horseshoe Bend to Emmett	1,797.64	
9	Emmett to Mid Slough	793.51	
13	Combined Waste	75.60	
12	Below 7 Mile Slough	457.74	
10	Letha to Payette	541.88	
	Total Flow rights	3,970.74	
	Total Storage Rights		516,794

Based on the tabulation of water rights presented in Table 2.4, it is clear that the vast majority of water use is in the lower basin, below Horseshoe Bend. In fact only about 8 percent of the water rights have points of diversion above Horseshoe Bend. This distribution of water use is primarily due to the topography and climate. Most of the land suitable for intensive irrigated agriculture is in the lower basin, below Black Canyon Dam, which is just upstream from the gage at Emmett. In the upper basin water is primarily used to irrigate pasture and hay. In addition to the direct flow rights, there are significant storage rights, the largest of which are associated with Deadwood and Cascade reservoirs. Additional water is used from these two sources during periods when streamflow is insufficient to satisfy all of the downstream rights.

2.2.5 Salmon release requirements

The development of a flow augmentation plan in the Columbia and Snake river systems began when the Northwest Power Planning Council adopted the Fish and Wildlife Program in 1982 which called for a water budget to benefit salmon migration. Amendments to the Program in 1991 and 1992 resulted in a system-wide plan. Biological Opinions were issued annually beginning in 1993 calling for 427,000 acre feet (427 kaf) to be provided from the U.S. Bureau of Reclamation's Snake River basin projects. This was continued in 1994 and in 1995, the 427-kaf flow augmentation schedule was adopted for continuation from 1995 through 1998.

Of the 427 kaf of flow augmentation that was to come from the Snake River basin, about 145 kaf was to be provided from the Payette River basin, coming from uncontracted storage in Deadwood and Cascade reservoirs. In 1994 all of the water for flow augmentation was released from Cascade Reservoir during the summer months. This resulted in poor water quality in the reservoir. In 1995, all of the water was released during the winter months resulting in low flow in the Payette River, which produced poor water quality in the lower river and decreased whitewater recreational opportunities. A negotiation in 1996 produced a plan to split the releases with half to occur in the summer, thus improving water quality and whitewater recreational opportunities and the other half during the subsequent winter months (Limbaugh, 1996a).

During 1996, approximately 150 kaf of reservoir storage was allocated to flow augmentation in the Payette basin (CRWMG, 1996) and the release was split between the summer and winter periods. The flow was verified at the Letha gage with any flow above 135 cfs considered flow augmentation water (Limbaugh, 1996a). Based on an accounting at the Letha gage, 75,168 acre feet was released during the summer months and 76,132 acre feet was released during the winter (Limbaugh, 1996b). The release of salmon flow augmentation began from Cascade Reservoir on July 12, 1996 and continued through August and early September. Releases from Deadwood Reservoir for both salmon flow augmentation and irrigation occurred between late July and the end of August (CRWMG, 1996).

3.0 Description and Evaluation of Available Models

There are two existing models that might be used for the verification of releases for streamflow augmentation in the Snake River basin: the Snake River Operations Model and the Accounting Model of the Idaho Department of Water Resources. After a brief description of the general requirements for such a model, each is evaluated in some detail with respect to its suitability for this application.

3.1 General model requirements

The primary requirements of a model for the verification of reservoir releases for instream flow augmentation are the ability to track water as it is released from one (or more) reservoirs and to determine whether that same amount of water has reached a selected point downstream. Most models that can be applied for this purpose simulate the water balance of the particular river basin on a reach by reach basis. Components of the reach water balance include inflow from the reach above and outflow to the reach below, natural accretions or losses, diversions, return of the unused portion of the diverted flow, and the storage and release of flow and evaporation losses when a reservoir is present. To apply the water balance approach requires that all but one of the components be measured or estimated so that the remaining component can be computed. Therefore, this approach requires a considerable amount of data. As the objective here is to make these estimates in real time, or at least near real time, the data must also be available on a real time basis.

In addition to the data required to specify the water balance, two additional but related issues also arise: the time interval of the calculation and the representation of the dynamics of the system. For the purposes of accounting for the releases of water from storage and its transport through the river system, it is desirable to follow the water balance of the basin on at least a daily basis; the time interval typically used to manage and distribute water for irrigation purposes. This being the case, the dynamics of the system, in particular the time required for water to traverse a reach of river and the effects of that travel on the flow rate due to the hydraulic attenuation of the channel system, become important and must be considered.

Hence, a model that is useful in verifying the releases of water for flow augmentation purposes must accurately represent the water balance and the dynamics of the river system at a daily time interval.

3.2 Snake River Operations Model (SROM)

The SROM (Hydroshere, 1992a) is a computer model of the Snake River system including the hydrology (streamflow and diversions) and management (water allocation and reservoir operations for water supply, flood control and hydroelectric power generation). It was developed to provide quantitative evaluations of changes in the water management of the basin as they relate to augmenting streamflow conditions for salmon migration. The model is an application of the Central Resource Allocation Model (CRAM), a network simulation and solution algorithm applied to water resources modeling.

3.2.1 SROM model formulation and operation.

The Snake River basin is represented in SROM as a system of links, representing the various river reaches, reservoirs and diversions in the system, connected at nodes where flow is added to the system (inflows), combined (confluences) and withdrawn from the system (diversions). Each link is assigned a "rank", representing a priority for moving water through that link. Water is then moved through the system by “solving” for the flow in each link of the network that optimizes a specified objective function subject to preserving the mass balance at each node (inflow of water is equal to outflow plus change in storage). The Out-of-Kilter Algorithm (OKA) is used to resolve the network and converge to the optimal distribution of flow.

SROM operates on a two-tiered time step, with a period and sub-periods specified at a year and a month respectively. Data (inflow and water demand data) are provided to run SROM on a monthly time step for the period from 1928 through 1989.

3.2.2 Suitability of SROM for flow verification

To evaluate SROM, we were provided with a compiled copy of the computer code and three manuals (Hydrosphere 1992a, 1992b, 1992c). Because SROM is an application of CRAM, which is a proprietary modeling package, the source code was not available. SROM was designed for and used to simulate flow in the basin on a monthly time interval (Hydrosphere 1992b, 1992c). However, for this study there is a need for a finer time resolution, down to at least a daily time step. The documentation does not address whether SROM can be applied at a shorter time interval and if so, how that can be accomplished. It was therefore necessary to test the flexibility of SROM to simulate the system at time intervals other than a month. Unfortunately, based on our experimentation with the code we were unable to determine how to apply SROM for a shorter time interval.

Even if it were possible to use the model at a daily time step, the dynamics of the system, as represented in the model, do not appear to provide an adequate description for that short of a time interval. As previously described the issues of lag time and attenuation in the system become more important as time intervals shorten. For the monthly time step used in SROM, it is not important to include these dynamic effects, however, when daily flow is considered, these effects become significant.

We therefore conclude that, in its existing form SROM is not appropriate for performing the simulations required to verify water deliveries for streamflow augmentation. Further, based on the existing documentation, we were unable to determine whether a shorter time step could be implemented given the proprietary nature of the code.

3.3 Idaho Department of Water Resources Accounting Model

The Idaho Department of Water Resources (IDWR) Accounting Model was developed for the purposes of managing water allocation in the Snake River basin in response to problems encountered during the very dry summer of 1977 (Sutter et al, 1983). The model is used to assist the local watermaster in accounting for the use of water from natural flow, based on the priority of water rights, and the management of and accounting for water use from reservoir storage where natural flow is insufficient to meet demand. It is also useful in providing short-term predictions of water demand that provides assistance in distribution during periods of shortage.

3.3.1 IDWR Accounting Model formulation and operation

The basis for the IDWR Accounting Model is a water balance for each river reach, accounting for inflows, outflows and the effects of reservoir storage and evaporation. For each day, the water balance for a particular reach is assumed represented as:

$$O = I + G - D - \Delta S - E$$

where:

- O is the measured outflow from the reach,
- I is the measured inflow to the reach from the upstream reach,
- G is the reach gain, the amount of water flowing into or lost from the reach due to tributary inflow, natural baseflow accretions or losses, and other sources such as irrigation return flows,
- D is the measured diversions from the reach,
- ΔS is the observed change in reservoir storage for the reservoir in the reach (increase in reservoir storage is positive), and
- E is the measured or estimated evaporation from the reservoir.

The Accounting Model allocates water that is diverted from the system to its source; that is either natural flow or stored water.

The accounting of water use is based on the computation of natural flow in the basin. This provides an estimate of the streamflow that would exist if there were no diversions or regulation in the reach. As a first step in the application of the Accounting Model, the natural flow that accumulates in each reach is computed, based on the equation:

$$G = O - I + D + \Delta S + E$$

To compute the reach gain requires that all other components of the water balance be either known based on measurements or estimated if observations are not available. The flow into each reach is adjusted (by one or more full days as required) to account for the estimated travel time through the system.

Once the gain is computed for each reach, it is accumulated in the downstream direction to estimate the natural flow (NF). The NF is available for allocation based on the water rights priority. Water use in excess of the natural flow comes from storage.

Having computed the natural flow for the river system, the Accounting Model then determines the source of water for each diversion, either natural flow or storage water and the amount of streamflow at each location that due to releases from reservoir storage. Given the accumulated natural flow in each reach, the calculation proceeds as follows:

- For each water right, the natural flow (NF) is allocated to each successive diversion, based on priority date, to determine the remaining natural flow (RNF) in each reach.
- Once the allocation is complete, the RNF is compared to the observed outflow from each reach to determine the amount of the observed flow that came from reservoir storage.
- Finally, the diversion rates are compared to the allocated natural flow to determine the amount of each diversion that came from reservoir storage.

An estimate of reservoir releases for streamflow augmentation is possible using the IDWR Accounting Model and, in fact, is a direct result of the second step in the process outlined above.

<u>3.3.2 Suitability of the IDWR Accounting Model for flow verification</u>

The ability of the Accounting Model to provide an accurate estimate of the flow at any point in the basin, and thus an accurate estimate of flow augmentation, depends on how well the underlying assumptions of the model are satisfied in implementation. In considering the development of the model, two questions arise regarding the model structure and implementation that could impact the accuracy of the calculation and should therefore be evaluated.

- The intensive nature of the measurements required to operate the model and the impact of inaccuracies in the observations, most particularly diversions, on the water balance calculations. Many diversions are either not monitored or are not measured as regularly as some of the other components in the reach water balance.
- The potential error involved in assuming that travel time is sufficient to describe the attenuation of water flow in the basin.

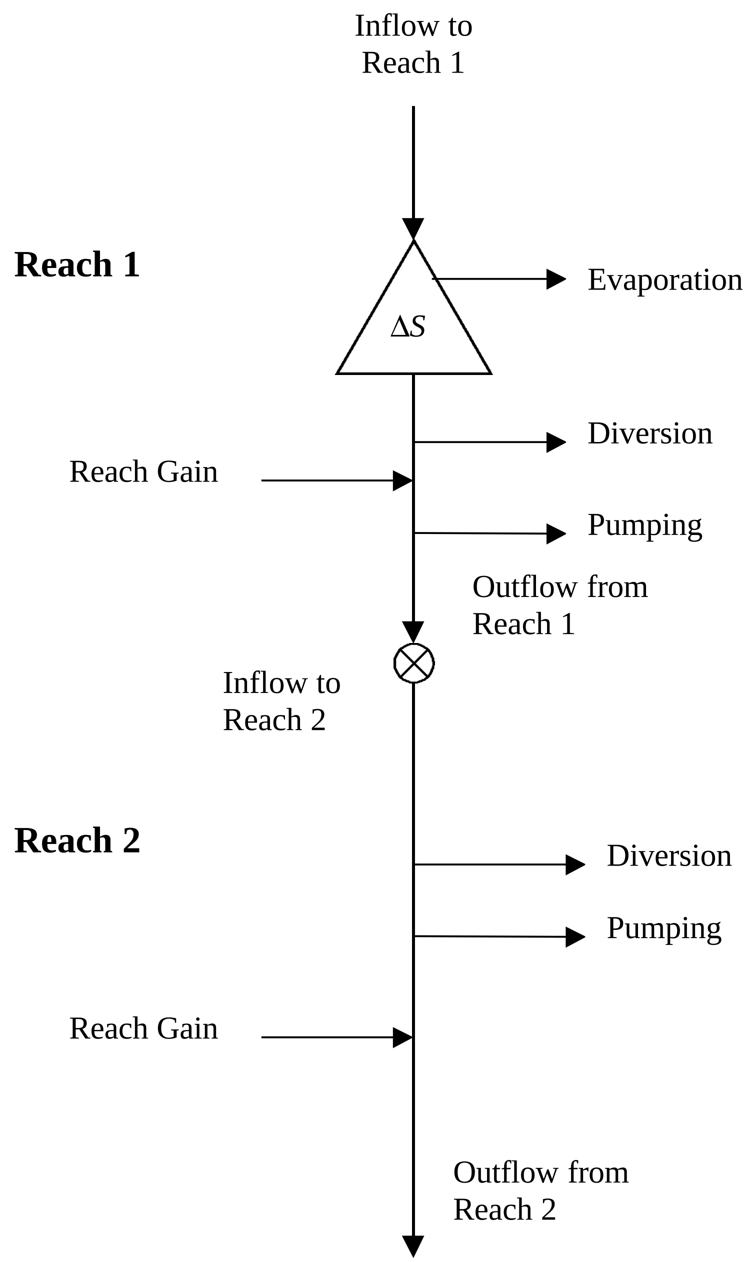
Each of these questions is evaluated conceptually and numerically as required for clarification in the discussion that follows.

<u>3.3.2.1</u> Operation of the IDWR Accounting Model: a simple example

To calculate the reach gain, and to ultimately estimate the amount of water from storage that is flowing in a particular reach, requires that each of the other components of the water balance be either measured or estimated. The inflow, outflow and change in reservoir storage in the reach are usually based on continuous observations at USGS or IDWR gaging stations. Diversions may be determined using continuous measurements, spot measurements, or estimates based on a knowledge of the hydraulics of the diversion structure or power records if withdrawal is by pumping. Reservoir evaporation is estimated based on observed pan evaporation.

Because the calculation to determine the amount of water from storage in a particular reach is a several stage process, it is most easily illustrated by a simple example. Consider the simple, two-reach river system shown in Figure 3.1. In this system, Reach 1 represents the headwater and

Figure 3.1. Schematic of the simplified example used to illustrate the calculations performed in the IDWR Accounting Model and the sensitivity of the model to inaccurate measurements and estimates of the inflows and withdrawals.



there is a single reservoir in this reach. Tributary and groundwater inflow are represented by the reach gain and there are diversions from both Reach 1 and Reach 2. If the water budget is completely specified from each reach, then it will be possible, by applying IDWR Accounting Model procedures, to investigate the sensitivity of the stored water calculation to errors in the other terms of the water balance.

Assume that the water budget is as specified in Table 3.1 in arbitrary units. Note that there is a water balance as all components (inflow, change in storage, diversion and reach gain) add to equal the outflow for each reach.

Table 3.1. Water balance components for the simple example system of Figure 3.1. Units are unspecified and arbitrary.

Water balance Component	Reach 1	Reach 2
Inflow (I)	0	5
Change in reservoir storage (ΔS)	-40	0
Evaporation (E)	5	0
Diversion (D)	40	20
Pumping (P)	10	5
Reach Gain (G)	20	115
Outflow (O)	5	135

In addition to the water balance components, information on the relationship of the diversions to water rights, including flow rate and priority date, are required. Consider that there are four water rights in the basin, two in each reach, with priority as given in Table 3.2.

Table 3.2. Water rights for the simple example illustrated in Figure 3.1

Water right priority	Reach	Diversion rate	Type of diversion/withdrawal
1	2	20	Diversion structure
2	1	40	Diversion structure
3	2	5	Pumping
4	1	10	Pumping

Assuming all terms of the water balance, except the reach gain, are measured (inflow, outflow, diversion, change in reservoir storage) or estimated (reservoir evaporation), the algorithm of the IDWR Accounting Model can be applied to estimate the natural flow and identify the source of water for each diversion. The calculations proceed as follows:

1. For each reach in turn, beginning with the upstream reaches, the reach gain (G) is computed from the water budget equation.

2. The natural flow (NF) is computed as the cumulative reach gain in the downstream direction considering the nature of the drainage network. (In this case there are only two reaches so the natural flow is simply the sum of the reach gain.

3. The natural flow is allocated to each water right, in priority order, based on availability.

4. The remaining natural flow (RNF) is computed after each water right is allocated. The allocation of water upstream, affects the RNF downstream but the allocation of water downstream, does not affect upstream water availability.

5. Once all of the water rights are allocated from natural flow, or the remaining natural flow is fully allocated, the stored flow component is computed as the difference between the observed outflow in the reach and the RNF.

6. The amount of each water right taken from storage is computed as the difference between the flow allocated from NF and the actual amount of water diverted from the stream.

These computations are illustrated in Table 3.3. First the reach water balance is computed to estimate the reach gain and the natural flow. Then the natural flow is allocated to the various water rights and the remaining natural flow is estimated for each reach. The amount of water in each reach due to storage is estimated and finally, the source of the water for each water right, either natural flow or storage water, is determined.

In this example, the natural flow conditions, without the reservoir or diversions, would produce an outflow of 20 units from Reach 1 and 135 units from Reach 2 as a result of natural accretion from tributaries and groundwater. This natural flow is computed from the water balance. However, the diversions, particularly those in Reach 1, require additional flow, which is released from the reservoir. The natural flow, when allocated, is sufficient to supply the diversion requirements in the lower reach, Reach 2, but is insufficient to satisfy the diversion requirements in Reach 1. Since all of the natural flow is allocated to the most senior right in Reach 1, any outflow must be due to releases from the reservoir, as indicated in the computation of the amount of outflow that comes from stored water. Finally, water that is diverted above the natural flow is allocated to stored water. As a result, 30 units (20 to satisfy the additional requirements of water right 2 and 10 to satisfy water right 4) must have come from reservoir storage. As a check on the calculations, the diversion from reservoir storage (30 units) and the outflow from reservoir storage (5 units) sum to the reservoir release (35 units, computed as the change of storage less the evaporation).

Table 3.3. IDWR Accounting Model calculations for the simple river system of Figure 3.1 using data from Tables 3.1 and 3.2.

Reach water balance and natural flow computation

Reach	O	I	D	P	dS	E	**G**	**NF**
1	5	0	40	10	-40	5	20	20
2	95	5	20	5	0	0	115	135

Allocation of natural flow to water rights

		Right 1		Right 2		Right 3		Right 4	
Reach	Natural flow	FA	RNF	FA	RNF	FA	RNF	FA	RNF
1	20		20	20	0		0	0	0
2	135	20	115		95	5	90		90

Amount of outflow that comes from stored water

Reach	Outflow	RNF	Stored flow
1	5	0	5
2	95	90	5

Allocation of stored water to diversions

Right	Flow	FA	Stored water
1	20	20	0
2	40	20	20
3	5	5	0
4	10	0	10

Abbreviations:

NF Natural flow, the accumulated reach gain
FA Flow allocation, the amount of natural flow allocated to a particular water right
RNF Remaining natural flow

3.3.2.2 Sensitivity of the IDWR Accounting Model to data inaccuracy

For the Accounting Model to perform in an accurate manner, data for each component of the water balance, except the reach gain, must be available in real time. Of particular concern are the data on diversions, especially those that are not associated with a large, organized irrigation activity where the withdrawal occurs at a major structure and the diversion rate is measured continuously. Many of the smaller diversions are not measured continuously. In these cases, records are not available and the rate of flow must be estimated. Uncertainty in the rate of diversion would presumably lead to errors in the water balance, errors in the estimation of reach gain and potentially to errors in the estimate of stored water flowing in the reach. The effects of inaccuracies in individual components of the water balance on the estimate of stored water flowing in the reach can be determined by evaluating the effect of changes in the diversion term of the water balance on the calculation of the amount of stored flow.

Considering the simple two-reach system again (Figure 3.1), suppose that the diversions due to pumping were not measured and were therefore not included in the calculation. This omission would produce the calculation shown in Table 3.4, where all of the other observations (outflows, changes in reservoir storage, evaporation and measured diversions) remain the same. Following the effect of omitting the pumping diversion through the calculation demonstrates the impact of errors in the observed or estimated water balance components.

As all components except the diversion terms remain fixed based on the measurements, the effect of the unmeasured diversions is an underestimate of the true reach gain and therefore the natural flow available for allocation. As can be seen in Table 3.4, there is no impact on the estimate of outflow that is the result of a the release of water from the reservoir. This lack of sensitivity to errors in the estimate of diversion is due to the calculation procedure. However, because the estimate of natural flow in Reach 1 is reduced by the amount of the unmeasured pumping diversion, the Accounting Model allocates that amount of the measured diversion (10 units in this case) to stored water rather than natural flow. Thus, the impact of the unmeasured diversion is on the individual or organization holding water right 2, who will be assessed for more storage water than was actually used (an additional 10 units in this case). In contrast, the junior water right in reach 1 (water right 4) is not assessed for the use of water that is actually from storage. The result of not measuring all of the diversions, then, does not effect the estimate of the outflow from storage but impacts the allocation of water that is diverted. As a result, those diversions that are measured are assessed for more stored water than they actually used.

From this simple demonstration, it appears as if the IDWR Accounting Model can be used to estimate the amount of water passing a particular point on the stream that has been released from a reservoir, if all other assumptions are accurate.

Table 3.4. IDWR Accounting Model calculations for the simple river system of Figure 3.1 assuming that the diversion due to pumping are not measured and are therefore not included in the calculation.

Reach water balance and natural flow computation

Reach	O	I	D	P	dS	E	**G**	**NF**
1	5	0	40	0	-40	5	10	10
2	95	5	20	0	0	0	110	120

Allocation of natural flow to water rights

		Right 1		Right 2		Right 3		Right 4	
Reach	Natural flow	FA	RNF	FA	RNF	FA	RNF	FA	RNF
1	10		10	10	0		0	0	0
2	120	20	100		90	0	90		90

Amount of outflow that comes from stored water

Reach	Outflow	RNF	Stored flow
1	5	0	5
2	95	90	5

Allocation of stored water to diversions

Right	Flow	FA	Stored water
1	20	20	0
2	40	10	30
3	0	0	0
4	0	0	0

Abbreviations:

NF Natural flow, the accumulated reach gain

FA Flow allocation, the amount of natural flow allocated to a particular water right

RNF Remaining natural flow

3.3.2.3 Time lag vs. flow routing to account for the attenuation of flows.

Once water is released from a reservoir or diverted from a river reach, the effects must travel through the channel system to the outlet. The time required for flow disturbances such as this to propagate through the system is based on the celerity or speed of the particular wave, which is proportional to, but greater than, the velocity of flow. The celerity, and therefore the travel time, is dependent on the channel characteristics causing flow to occur (principally the slope) and providing the resistance to flow (the channel roughness and cross section). In addition to the time lag, a disturbance may also be attenuated by the channel system, resulting in a change in the timing of flow in the downstream direction. This phenomenon is most often associated with flood waves where the peak flow decreases in the downstream direction, in the absence of substantial lateral inflow, due to dynamic effects of the flow. Of interest is how important each of these phenomena are and how well the IDWR Accounting Model represents them. The evaluation will focus first on assessing whether there is any significant attenuation that should be considered and then on the effects of inaccuracies in estimating the travel time

In the IDWR Accounting Model, the effect of travel time in the channel system is accounted for by lagging the observed flow by one or more days depending on the location in the basin, thereby accounting for the time required for water to move through the basin. The time lag between the various reaches of the Payette River and the basin outlet (taken to be the gaging station near Payette) is shown in Table 3.5. The assumption in the model is that the effect of water diverted from or released into an upstream reach during a particular day will be experienced in its entirety in a downstream reach one or more days later, depending on the travel time.

Table 3.5. Travel time to the mouth of the Payette River (USGS gage near Payette) assumed fore each river reach in the IDWR Accounting Model.

IDWR reach number	Reach name	USGS Station Number	IDWR Accounting Model travel time to the Payette gage (days)
1	South Fork at Lowman	2350	2
2	Deadwood below Deadwood	2365	2
3	Payette near Banks	No gage	1
11	Upper North Fork	238322	3
4	North Fork at McCall	2390	3
5	At McCall to Cascade	2450	2
17	L. Payette Lake to Cascade	2400	3
6	North Fork – Cascade to Banks	2460	1
7	Banks to Horseshoe Bend	2475	1
8	Horseshoe Bend to Emmett	2495	1
9	Emmett to Mid Slough		1
13	Combined waste		1
12	Below 7 Mile Slough	2500	1
10	Letha to Payette	2510	0

Assuming a fixed time lag for flow from one reach to another downstream accounts for travel time. However, this approach does not represent any attenuation of the flow that may occur. The validity of this assumption depends on the hydraulics of the river system. One approach to assessing the effects is to dynamically model the flow through at least selected reaches of the system using a hydraulic model to determine the travel time and attenuation effect, if any, on the flow at various downstream points. An analysis such as this would require data that are either not readily available, such as streamflow data at time intervals less than one day, or are not available at all, such as the tributary and groundwater inflows and possibly some diversions within the reach. Alternatively, an assessment of the assumptions can be made by using a simple but physically realistic model of unsteady flow to determine how the characteristics of the channel system affect the flow. Such an assessment was conducted (Appendix B). In the specific case of the Payette River segments investigated, the rate of flow attenuation was determined to be low to nonexistent indicating that the fixed lag time approach is an adequate approximation of river dynamics.

The remaining question is how errors in travel time affect the results of the Accounting Model. The travel time units used in the Accounting Model are whole days (see Table 3.5). It is unlikely that this is precisely the case so a simple evaluation of the impact of an error in the assumption of travel time was performed. In this experiment, a simple, 3-reach river system, shown in Figure 3.2, was developed with a reservoir as the first (upper) reach and the second and third reaches being typical of those in the Accounting Model with diversions and a specified reach gain. A set of arbitrary flow and diversion data with a time interval of 6 hours was developed for the system. The travel time for the second reach was half of a day and for the third was another half day. The Accounting Model calculations were then performed assuming the travel time in the first reach was zero, that is all flow entering the reach flowed through in the same day, while the travel time for the third reach was assumed correctly to be one day from the upper reach. The inflow, reach gain, reservoir release and diversion data used for the system are provided in Table C3.1 of Appendix C for each time period. The results of the Accounting Model calculations for this example are also presented in Appendix C as Tables C3.2, a through e. In each table, the values are those for the particular day indicated. As a result, the inflow to reach 3 is the outflow from reach 2 in the previous day to account for the assumed one-day travel time. The results of this experiment demonstrate that the incorrect travel time affects the estimate of stored flow in each reach on any given day but the aggregate stored flow over a longer period of time is preserved.

The daily flow for reaches 2 and 3, as estimated by the model, were incorrect due to the mis-specification of travel time. A comparison of the actual stored flow (based on the specifications in the example) and that computed based on the Accounting Model procedure is presented in Table 3.6. As the computations are based on the actual (observed) flow in the reach, and the model does not allow for the half-day travel time in reach 2, the estimate of stored flow in days 2, 3 and 4 are incorrect in reaches 2 and 3. However, when aggregated over the period of 5 days, the total stored flow passing the reach is correct. Thus, an error in the travel time results in an error in the estimated value for any individual day but the aggregate estimate of stored flow over several days is accurate.

Figure 3.2. Configuration of simplified system used to assess the effects of errors in travel time on streamflow calculations.

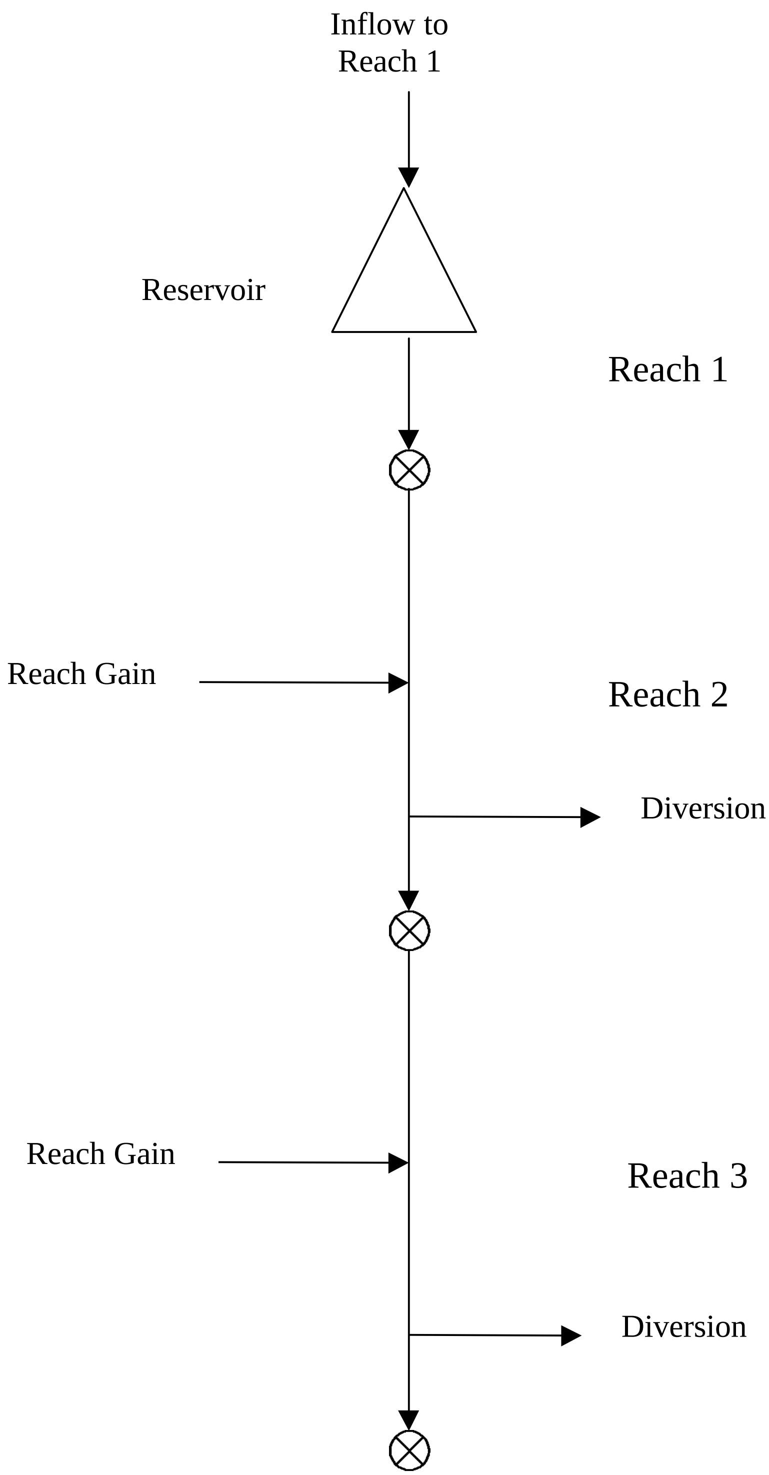


Table 3.6. Comparison of actual and computed stored flow contributions to streamflow for a hypothetical application of IDWR's Accounting Model to test the model's sensitivity to errors in estimated travel time.

	Reach 1[1]		Reach 2[1]		Reach 3[1]	
Day	Actual Stored Flow	Computed Stored Flow	Actual Stored Flow	Computed Stored Flow	Actual Stored Flow	Computed Stored Flow
1	0	0	0	0	0	0
2	500	500	250	500	0	250
3	0	0	250	0	500	0
4	0	0	0	0	0	250
5	0	0	0	0	0	0
Total	500	500	500	500	500	500

1 See figure 3.2.

3.3.2 Example of IDWR Accounting Model operation and output

The IDWR Accounting Model is applied to the Payette River each day of the year, generating a record that is used to assign diversions to either natural flow or stored water and to estimate the amount of unused storage water that passes out of the basin. The complete copy of the information generated by the model for the period July 1, 1996 through September 30, 1996 is presented in Appendix D. As an aid to interpreting this detailed output, an example is presented for the reach of the North Fork from McCall to Cascade (reach 5 in the IDWR model) during the period from July 1 through July 6, 1996. This reach is selected because it includes all of the elements of the reach water balance equation, including reservoir storage and evaporation from Cascade Reservoir.

The water balance equation presented in section 3.3.1 is applied each day based on data for streamflow into and out of the reach, change in reservoir contents and estimates of reservoir evaporation and diversion. The results of the calculation of reach gain presented in Appendix D are slightly different from that in the simplified example. In the model, the reach gain shown for a particular day is a four-day average value of the calculated gain for that day and the previous three days.[1] This calculation is shown in Table 3.9 for the first six days in July. The values in Table 3.7 are taken from the IDWR Accounting Model output presented in Appendix D.

Due to travel time in the basin, the date in Table 3.7 is not the date of the observed flow at Cascade. Rather it is the date the combined effects of upstream hydrologic events were expressed in the stream reach between Letha and Payette, the bottom of the watershed (see Appendix D). In this example, hydrologic events in the McCall to Cascade reach three days

[1] IDWR indicates that the rationale for using a four-day average of reach gain is based on the travel times for water to move through the basin. That is, water available in one reach may not be available at a downstream location until up to four days later in extreme cases. This averaging process smoothes the unrealistic variations in reach gain from day to day inherent to the raw calculations.

Table 3.7. Computation of reach gain for the reach from McCall to Cascade as performed in the IDWR Accounting Model. Numerical values are taken from the IDWR Accounting Model output, Appendix D, for the days indicated.

Date	Outflow (O)	Inflow (I)	Diversion (D)	Change in Storage	Evaporation (E)	Reach Gain (G)	Average reach Gain
July 1, 1996	1492	420	0	-143	95	1024	*
July 2, 1996	1493	341	0	-286	213	1079	*
July 3, 1996	1324	347	0	143	169	1289	*
July 4, 1996	1158	500	0	0	0	658	1013
July 5, 1996	1336	522	0	0	264	1078	1026
July 6, 1996	1499	599	0	822	132	1854	1220

* Average reach gain based on previous 4 days so values are not presented

prior to the specified date contribute to flow conditions in the Letha to Payette reach. That is, the lag time is three days. The change of storage value for Cascade Reservoir is taken from the table summarizing the change of reservoir contents located in the left center of the summary page for each date. Although there is no diversion from this reach during the chosen period, the "Total Reach Diversion" column on the IDWR Accounting Model output represents the sum of the individual diversions for that reach, reported individually on the page titled "Payette River Diversion Data" following the summary of the model output.

3.4 Selection of model for use in the case study

Because it was not possible to determine from the documentation precisely how the SROM model operated and whether it could be adjusted to run at a daily time step, it was deemed unsuitable for use in verifying reservoir releases for instream flow.

The IDWR Accounting Model is currently being used as an accounting and management tool in the basin and is a reasonable, if simplified, approach to determining water availability, including the source of the water. The model is quite data intensive, requiring observations on all of the major sources and uses of water, some of which is not collected on a regular basis and must be estimated. However, given the computational method employed in the model, the estimate of the stored water (water released from reservoir storage) flowing past a prescribed location is not sensitive to inaccuracies in the estimation of water use. In addition, the characteristics of the Payette River basin are such that the use of a fixed time lag to account for travel time in the basin appears to be appropriate. Errors in the specification of travel time affect the estimates of the model on a daily basis but the aggregate estimates of stored flow, the variable of primary interest in this analysis, is still accurately estimated.

We conclude that the IDWR Accounting Model is the best currently available tool for use in verifying reservoir releases for flow augmentation purposes. The subsequent analysis is based on this model and draws heavily from the application of the model to the Payette River basin during the summer of 1996.

4.0 Verification of July and August 1996 Flow Augmentation

Because the purpose of this study is the evaluation of tools for verification of reservoir releases to augment instream flow for salmon migration, it is useful to assess how the IDWR Accounting Model was used for that purpose during the summer of 1996. As discussed in the previous chapter, the 1996 reservoir releases were split equally between the summer and winter months. The summer stored water release for flow augmentation, projected to be 75 kaf, began in early July and continued through early September. Streamflow accounting for these releases was performed using the IDWR Accounting Model results at the Letha gage. Of concern is whether the all of the flow released from Cascade and Deadwood reservoirs reached Brownlee Reservoir. In this evaluation, it is assumed that if the flow reached the streamgage near Payette, then it has, in effect, reached Brownlee Reservoir as this gage is very near the confluence of the Payette and Snake rivers which is, in turn, is near the head of the reservoir.

1996 was an excellent water year with flow well above average as a result of ample winter precipitation (Limbaugh, 1996a). Estimated natural flow at Horseshoe Bend, based on the IDWR Accounting Model, was 3.5 million acre-feet (Maf). In comparison, the average annual flow of the Payette River near Payette is approximately 2.2 Maf. All reservoirs in the Payette River system filled during the year.

The IDWR Accounting Model is the best currently available tool for verifying reservoir releases for instream flow augmentation, even given the limitations discussed in Chapter 3. In evaluating the application of the model during the summer of 1996 there are two issues that need to be addressed. First, during 1996, not all of the water users in the basin were considered during the model operation and second, the verification of flow was based on the streamgage at Letha rather than the gage at the mouth of the river near Payette.

4.1 Effects of unmeasured diversions

Although all of the water users have now been added to the IDWR Accounting Model as it is applied to the Payette River, in 1996 power records were used to estimate water use between Black Canyon Dam and Gardenia and above Gardenia the diversions and water rights were not considered. The impact of failing to include all of the diversions has been demonstrated in section 2.3.2.2. In that simplified system, it was observed that excluding known diversions from the system does not impact the estimate of the amount of streamflow from storage but does impact the allocation of water use between natural flow and storage. So, even though this omission may affect the assessment of charges for the use of water from storage, it does not impact the estimation of streamflow that results from storage.

4.2 Flow augmentation estimates using the Letha vs. the Payette gage

The Accounting Model uses the Letha stream gage to account for the flow augmentation releases. As this site is well above the mouth, using the Letha site assumes that water use below that point does not impact the amount of stored water in the river.

The detailed output of the IDWR Accounting Model for his period was obtained from the IDWR (Sheryl Howe, personal communication) and evaluated to compare the estimated amount of water from storage passing each location and the diversion of water from storage in that reach. The complete output for July 1 through September 30 is provided in Appendix D. Table 4.1 is a portion of the output from the IDWR Accounting Model for August 14, 1996, a date selected at random. The Letha gage is the outflow of the reach titled “Below 7 Mile Slough” and the Payette gage is the outflow to the reach titled “Letha to Payette”. Stored flow is an estimate of the amount of streamflow resulting from reservoir releases. Observing the stored flow for each of these reaches suggests that, although there was 588 cfs of water from storage passing the Letha gage on this day, only 516 cfs passed the Payette gage. This suggests that some of the stored water passing the Letha gage did not reach the Snake River.

Table 4.1. IDWR Accounting Model output showing stored flow and diversions.

IDWR reach designation					Diversion flow	
No.	Name	Actual date	Actual flow	Stored flow	natural	total
1	S. Fork at Lowman	12-Aug	637	0	0	0
2	Deadwood below Deadwood	13-Aug	645	488	0	0
3	Payette near Banks	13-Aug	1,573	488	0	0
11	Upper N. Fork	11-Aug	2	0	0	0
4	N. Fork at McCall	11-Aug	51	39	0	0
5	At McCall to Cascade	12-Aug	1,328	1200	0	0
17	L. Payette Lake to Cascade	11-Aug	10	10	0	0
6	N. Fork - Cascade to Banks	13-Aug	1,451	1210	0	0
7	Banks to Horseshoe Bend	13-Aug	3,051	1695	0	0
8	Horseshoe Bend to Emmett	13-Aug	1,417	625	570	1636
9	Emmett to Mid Slough	13-Aug	889	591	684	719
13	Combined Waste	13-Aug	79	-44	0	44
12	Below 7 Mile Slough	13-Aug	723	588	286	289
10	Letha to Payette	14-Aug	1,032	516	382	410

A compilation of the stored flow at Letha and Payette for the period of July 1 through September 3, the period for which flow augmentation releases were made, and from July 1 through September 30, the last day for which the detailed output was obtained, is shown in Table 4.2.

Table 4.2. Total stored flow in acre-feet passing the Letha and Payette gages for the periods indicated, based on the IDWR Accounting Model output.

Time period	Letha gage	Payette gage
July 1 – September 3	75618	67761
July 1 – September 30	78204	69800

Although this table suggests that stored flow was used below Letha, further investigation and discussion of this matter with IDWR (Sheryl Howe, personal communication) provides an explanation for the situation. The reach below Letha gains a considerable amount of water due to both surface and subsurface irrigation return flow. As a result, the reach gain is sufficient to accommodate diversion well in excess of established water rights. As a result of the natural increases in flow, a volume equivalent to the stored flow that passes Letha, does reach the outlet of the basin. However, the Accounting Model operates in a manner that automatically assigns any diversion in excess of the diversion right to stored flow. Thus, if diversions in the reach between Letha and Payette exceed the diversion right, the Accounting Model assigns the excess to storage water, even if there is sufficient natural flow to satisfy the diversion. This was the case during the summer of 1996. Because diversions in the lower reach exceeded the diversion right, they were assigned to storage water, even though the reach gain was on the order of 1000 cfs.

5.0 Summary and Conclusions

5.1 Summary

This study evaluated whether currently available tools are adequate to verify that water released from U.S. Bureau of Reclamation reservoirs to augment instream flow has reached Brownlee Reservoir. In addition, an accounting of the instream flow releases during the summer of 1996 was performed. Two models currently exist that could be used for the purposes of flow verification: the Snake River Operations Model (SROM) and the Idaho Department of Water Resources (IDWR) Accounting Model. Each was evaluated for its suitability in performing the required calculations.

Given the size and hydrologic complexity of the Snake River basin, a case study approach was selected to determine the suitability of the existing models for flow verification. The Payette River basin was selected as the study basin because it was a manageable size and included a major storage project, Cascade reservoir, from which a substantial portion of the flow augmentation releases were made and because data on streamflow and water use in the basin were available to support the analysis.

As described in Section 3.2.2, insufficient information was available to determine whether or how the SROM could be applied to the task of verifying streamflow releases.

The IDWR Accounting model was evaluated in detail. The calculation procedure of the model was demonstrated and the assumptions were evaluated. The model's sensitivity to inaccuracies in diversion data and the estimation of travel time were evaluated. The model was found to be simple, yet robust and relatively insensitive to errors with regard to producing aggregate estimates of water released for instream flow.

An evaluation of the amount of stored water released for flow augmentation purposes during the summer of 1996 was performed using IDWR's Accounting Model. This assessment showed that the model accurately calculated the accumulation of flow released from storage passing the Letha gage. However, a similar calculation performed at the Payette gage indicated that a lesser amount of stored water actually reached the Snake River (see Table 4.2). Further evaluation revealed that the river gains a considerable amount of flow in this lower reach and that diversions in excess of the diversion right were automatically assigned to storage rather than natural flow, even though sufficient natural flow was available.

5.2 Conclusions

There were two primary objectives of the study: evaluation of the models available for verifying salmon flow augmentation, and verification of the flow augmentation for the summer of 1996 using one or more of those models, commenting on their utility and suitability. The conclusions are organized by these objectives.

5.2.1 Evaluation of model suitability

1. The SROM could not be evaluated in detail due to the proprietary nature of the model and as a result it was not possible to determine with complete certainty whether, in its present form it could be used for flow augmentation verification. However, since the model was designed to operate on a monthly time step, it is probable that there would be some difficulties when applied to a daily time step given the importance of the system dynamics at the shorter time interval.

2. The IDWR Accounting Model is based on a simple water balance for each reach in the river system and appears to be appropriate for the purposes of flow verification for the following reasons:

    - The model operates on a daily time step and even though several simplifying assumptions are used to estimate system dynamics, for situations where the result is summed over a longer period of time, the total (such and the aggregate of flow augmentation) should be only slightly affected.
    - Even though the model is data intensive, the calculation procedure is such that errors in the diversion estimates do not impact the estimate of stored flow passing a selected point in the river system.

This leads us to conclude that the IDWR Accounting Model is currently the best available tool to verify delivery of flow augmentation water released from BOR reservoirs in the Snake River basin.

5.2.2 Verification of summer 1996 flow augmentation

1. The Payette River system is a reasonable location for a case study of flow verification because there is a substantial flow augmentation requirement and water accounting in the basin is being done by the IDWR.

2. In the Payette River basin, verification of streamflow for flow augmentation occurs at the Letha gage, which is not the furthest downstream point in the basin. Using the IDWR Accounting Model output for the summer of 1996, the total amount of stored water passing the gage near Payette, at the confluence with the Snake River, is less than at Letha due to the computation methods applied in the model (see Table 4.2). The lower river is a complex system of water use and there is a considerable amount of return flow during the irrigation season that occurs between the Letha and Payette gages. This return flow is more than sufficient to satisfy the natural flow rights of the water users in the reach (Sheryl Howe, IDWR, personal communication). However, when water in excess of established water rights is used, the Accounting Model allocates it to stored flow, even though there may be sufficient excess natural flow.

3. To the extent that there are unmeasured diversions between Letha and Payette, it is not possible to clearly track the water released for salmon flow augmentation downstream from Letha using reported stored flow from IDWR's Accounting Model. That is, the

model would show less stored water flowing in the stream than actually occurred (see Table 4.2). Verifying that sufficient stored water passed Payette could be accomplished by comparing the estimated reach gain between Letha and Payette to the difference (loss) between stored flows at Letha and Payette. When the reach gain exceeds the stored flow loss, the amount of stored water passing Letha can be assumed to have reached Payette. This was consistently the case in 1996.

We conclude that the IDWR Accounting Model's capability to clearly and accurately track stored water releases and deliveries for instream flow augmentation in the Payette River basin would be improved if each diversion was identified and accurately measured.

6.0 References

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